DOCUMENT RESUME

ED 137 314 SP 010 970

AUTHOR Tennyson, Robert D.; Tennyson, Carol L.
TITLE Content Structure as a Design Strategy Variable in Concept Acquisition.
PUB DATE Apr 77
NOTE 25p.; Paper presented at the Annual Meeting, American Educational Research Association (New York, New York, April 4-8, 1977)

EDRS PRICE MF-$0.83 HC-$1.67 Plus Postage.
DESCRIPTORS Computer Assisted Instruction; Curriculum Design; *Educational Research; *Effective Teaching; *Instructional Design; Instructional Improvement; *Instructional Materials; *Sequential Learning; Teaching Methods

ABSTRACT

Three methods of sequencing coordinate concepts (simultaneous, collective, and successive) were investigated with a Bayesian, computer-based, adaptive control system. The data analysis showed that when coordinate concepts are taught simultaneously (contextually similar concepts presented at the same time), student performance is superior to either a collective (clustering the concepts in subgroups) or successive (concepts presented separately) sequence. Although time on-task was not different between the groups, an effectiveness ratio (posttest score minus pretest score divided by time on-task) showed that the simultaneous sequence was more effective in terms of student learning and economy of time that the other two sequences. (Author)

****
* Documents acquired by ERIC include many informal unpublished *
* materials not available from other sources. ERIC makes every effort *
* to obtain the best copy available. Nevertheless, items of marginal *
* reproducibility are often encountered and this affects the quality *
* of the microfiche and hardcopy reproductions ERIC makes available *
* via the ERIC Document Reproduction Service (EDRS). EDRS is not *
* responsible for the quality of the original document. Reproductions *
* supplied by EDRS are the best that can be made from the original. *
****

ED137314

Content Structure as a Design Strategy Variable in Concept Acquisition

Robert D. Tennyson

University of Minnesota

and

Carol L. Tennyson

Northern States Power Company

U S DEPARTMENT OF HEALTH, EDUCATION & WELFARE NATIONAL INSTITUTE OF EDUCATION

THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL NATIONAL INSTITUTE OF EDUCATION POSITION OR POLICY

Presented at the

American Educational Research Association

April, 1977

Annual Meeting

New York, New York

SP010 990

Content Structure as a Design Strategy Variable in Concept Acquisition

The question of how to sequence instructional material has been seriously considered and researched during this century (Dewey, 1916; Rugg, 1927; Tyler, 1950; Bruner, 1960; Suppes, 1966; Gagné, 1970; Posner, 1974; R. Tennyson & C. Tennyson, 1975). Although no single instructional design prescription is available, there is evidence to show that the content structure can make a difference in terms of performance and rate of acquisition in learning concepts (Houtz, Moore, & Davis, 1973; R. Tennyson, 1973). As background for the arrangements of content elements which were tested in this study, the previous research which has identified variables that are relevant to concept acquisition will be reviewed.

In the design of learning environments, considerable attention is given to the ordering of the instructional stimuli (content elements). This function refers to structuring the content to facilitate learning. In conceptual learning, researchers have demonstrated that the content structure consists of a set of empirically defined design strategies (Houtz, Moore & Davis, 1973; Klausmeier, 1976; Klausmeier, Ghatala & Frayer, 1974; Merrill & R. Tennyson, 1977a; Stolurow, 1975; Tennyson, Steve, & Boutwell, 1975). The content structure design strategies for conceptual learning include the following: (a) the presentation format of the definition; (b) the relationship of the examples; (c) the relationship of the examples and non-examples, (d) instances of varying degrees of difficulty; and (e) a system for selecting the appropriate number of instances. A sixth strategy which has not been researched in reference to conceptual learning is the relationship between coordinate concepts having contextual similarity.

The term contextualism comes from memory research (Jenkins, 1974), and refers to the study of the memory process, not in the form of isolated associative learning, but rather in a broader form such that the sources and structure of memory are studied. In concept learning, the sources and structure would refer to the placement of a given concept in relationship to other concepts having a similarity of attributes. This relationship implies that certain concepts would be subordinate while others would be superordinate. A third relationship for a given concept, would be with those concepts which are placed in the same general location in the content structure. Merrill and R. Tennyson (1977a) defined these concepts, which are neither subordinate nor superordinate as coordinate concepts. The importance of this coordinate relationship was shown in the research findings (R. Tennyson, Woolley & Merrill, 1972; R. Tennyson, 1973) that nonexamples contribute to conceptual learning if the nonexamples are matched, by variable attributes, to examples. However, this previous research was focused primarily on the learning of one concept, although the matched nonexamples were selected from contextual similar (coordinate) concepts. One recent study (R. Tennyson & C. Tennyson, 1975) has focused on the learning of contextual similar rules, and forms the basis of the content structure variable investigated in this study. That study dealt with the question of the use of negative instances (nonexamples in concepts) in rule learning. Three conditions of the variable were tested. In the first condition, simultaneous, the two contextually similar rules were presented concurrently such that an instance from one rule was paired to an instance of the second rule by matching variable attributes. The second condition, random, was a sequence in which the rules were presented concurrently, but instances were paired randomly with no attempt at relating one to another. For the

third condition, successive, the ruels were presented separately in a linear order. The hypothesis was that presenting rules simultaneously would facilitate rule acquisition more than presenting the same rules successively because learner attention would be directly focused on the differences of application between the rules. The results between the two presentations were striking; when the two rules were displayed separately, posttest performance was below 50% compared to 86% performance on the simultaneous condition.

Applying the findings of previous research on concept design strategies, the appropriate content structure for coordinate concepts would be a simultaneous presentation. A simultaneous presentation would group the instances of the coordinate concepts in rational sets such that each set include an example from each concept. Furthermore, the instances within a rational set would have similar variable attributes. Having similar variable attributes would focus student attention on the differences of the respective critical attributes. This design strategy has been shown to teach discrimination (e.g., Houtz, Moore, & Davis, 1973; R. Tennyson, 1973). Between the rational sets, the variable attributes should be different; demonstrating the scope of the various coordinate concepts. This design strategy of presenting divergent variable attributes within a concept teaches generalization (e.g., R. Tennyson, Woolley, & Merrill, 1972; Merrill & R. Tennyson, 1977b).

Alternative content structures to test the simultaneous sequence, are of two forms. First, a structure which clusters coordinate concepts into groups based upon similarity of critical attributes. That is, in coordinate concept groups which have a range of critical attributes, it is possible to cluster concepts according to overlapping of the critical attributes. This type of structure grouping termed collective, pr sents sets of instances which only include the clustering concepts, thus, the student is not given the opportunity

to contrast for entire range of the coordinate concepts. In other words, the student learns to generalize within a concept class, but fails to learn discrimination between the coordinate concepts. This content structure is similar to the treatment used by R. Tennyson (1973) when nonexamples were not included in the learning task, and the students failed to learn the concept entirely.

A second alternative content structure is a successive presentation of the coordinate concepts. This sequence was used by R. Tennyson and C. Tennyson (1975) in studying a simultaneous presentation of contextually similar rules. The successive sequence presents each concept separately, thus students see no contrasting of the various critical attributes. The implication is of course that students will not be able to discriminate between instances of coordinate concepts.

Research Hypothesis

The independent variables investigated in this research study were content structure and management strategy. Each of the variables were extensions from previous research. Content structure refers to the sequencing of the content elements, and in terms of this study on conceptual learning, that structure is in relationship to coordinate concepts. Three content structure variables were tested: simultaneous, presenting the coordinate concepts concurrently with instances (one from each concept) presented in rational sets; collective, presenting coordinate concepts in clusters according to similarity of critical attributes, with instances presented in clustered groups (i.e., all instances from one cluster presented before the next); and successive, presenting coordinate concepts separately, with instances representing the first concept presented in their entirety prior to presenting instances representing the next concept, and so forth. The research hypothesis was that

presenting coordinate concepts simultaneously would facilitate concept acquisition more than presenting the same concepts either collectively or successively because learner attention would be directly focused on the differences of the critical attributes between the concepts.

Method

Participants

Participants (N = 90) in the research project were volunteer junior and senior high school students (male and female) from Apple Valley Senior High School, District 196, Minnesota. This age group was selected as representative of students whose curriculum materials include conceptual learning objectives. They were enrolled in the three general psychology classes which were offered as electives. Students were randomly assigned to the three content structure treatments.

Learning Program

The coordinate concepts selected for this study were the psychological concepts: positive reinforcement, negative reinforcement, positive punishment and negative punishment. The superordinate concept was consequences of behavior, while the subordinate concepts were stimulus, aversive (stimulus) and attractive (stimulus). An assumption of the coordinate concept structure is that when several concepts of a content taxonomy are taught concurrently, the nonexamples of any one concept are the examples of other concepts of the taxonomy (Merrill & R. Tennyson, 1977a). This allows the defining (critical) attributes of the taxonomy to be standardized and allows the variable attributes to be manipulated by both the examples and nonexamples in a way to focus on the critical attributes with such factors as degree of instance difficulty, relative importance of the variable attributes, cause and effect principles, and other relationships among concepts. Therefore, to establish the critical attributes of the four psychological concepts and to place the definitions in an algorithmic framework, three subordinate concept definitions preceded the coordinate concept definitions. These defined concepts were stimulus, attractive stimulus, and aversive stimulus. The understanding of these subordinate

concepts were crucial to the student's learning of the coordinate concepts. The subordinate concept definitions were as follows:

STIMULUS: An agent, action, or condition which causes a response.

ATTRACTIVE STIMULUS: Condition, object, or event which an organism would "want" or "work for."

AVERSIVE STIMULUS: Condition, object, or event which an organism will work to "get away from" or "avoid."

The definitions of the coordinate concepts were as follows:

POSITIVE REINFORCEMENT: Occurs when an attractive stimulus produces a desirable (or pleasant) outcome.

NEGATIVE REINFORCEMENT: Occurs when an attractive stimulus produces an undesirable (or unpleasant) outcome.

POSITIVE PUNISHMENT: Occurs when an aversive stimulus produces a desirable (or pleasant) outcome.

NEGATIVE PUNISHMENT: Occurs when an aversive stimulus produces an undesirable (or unpleasant) outcome.

Instances used in the tests and learning program were written according to the concept strategy given by Woolley and R. Tennyson (1972; cf Houtz, Moore, & Davis, 1973; Klausmeier, 1976). The difficulty of each instance was determined by an instance probability analysis (using the students, $N = 24$, in the formative evaluation) according to procedures outlined by R. Tennyson and Boutwell (1972). A total of 88 instances were used in the learning program (40 total) and tests (24 total in each). The instructional instance pool contained ten instances of each concept. So, at maximum, a student could have received 40 instances before taking the posttest. Each example contained two lines so all of the instances were parallel in length and arrangement. The instances were intentionally brief, easy to read, and imagistic. Each treatment group employed the same instance pool. The learning program retained the same response format as the two tests, except that in the program after the response was made the student received feedback on whether the response was correct or incorrect.

In managing the presentation of these various content structure, an adaptive control system (R. Tennyson & Rothen, in press) regulated by a computer-based Bayesian probability model, selected the number of instances presented to each student based upon the student's pretask and ontask performance in relationship to the learning objective. The computer system provided instant feedback by responding to the entry with either the work correct or the word incorrect.

Treatment Programs

The three computer-based instructional treatment programs were developed as follows.

Group 1: Simultaneous

The adaptive control system was used with a simultaneous presentation of all four coordinate concepts. The four concept definitions and instances were presented at the same time. The student received the instances in sets of four--one from each concept. The instances in each rational set were arranged randomly and no two sets had the same pattern. The adaptive control strategy prescribed the number of instances needed per concept by use of the pretask data (premeasure score on syllogisms and confidence rating weighted pretest score), and adjusted the number according to on-task responses. When a student reached the criterion level for any concept, that particular concept was dropped from further sets. The sets reduced in size as the student mastered the concepts until, after the fourth criterion level was reached or the instructional instance pool was exhausted, the program stopped.

Group 2: Collective

This treatment consisted of the adaptive control system with a collective presentation of the coordinate concepts. The concepts were clustered into two groups: positive and negative reinforcement; positive and negative

punishment. The student first received in the learning program as many reinforcement instance sets as needed in order to meet the criterion level or until the instance pool was exhausted and, then, received punishment instance sets until he or she reached criterion or the instance pool was exhausted.

Group 3: Successive

This third treatment used the adaptive control system with a successive presentation of the coordinate concepts. The student received the instances in total sets: first the positive reinforcement instances, then the negative reinforcement instances, then the positive punishment instances and, finally, the negative punishment instances. For each concept, the student received as many instances as needed to reach criterion. He or she was then branched to the next concept set. If the pool was exhausted before criterion level was reached, the student continued to the next set. After the last concept, negative punishment, when the student reached the criterion level or the pool of instances was exhausted, the program stopped.

Bayesian Probability Model

A Bayesian adaptive model (Rothen & R. Tennyson, in press) was used to select the number of instructional instances which each student in the adaptive treatment groups would receive. The pretask score on syllogisms and pretest score established a prescribed number of instances for the learning program. The estimate of the student's ability to learn the concept was characterized in probabilistic terms. Then, the on-task responses modified that prescription. Since four concepts were presented, the adaptive program actually calculated each concept separately. The pretest included six instances of each of the concepts. The criterion level was set for each concept at total

mastery. Therefore, if a student answered all six instances of any concept correctly he or she received none of the instances for that concept in the learning program of the simultaneous or successive treatments. In the collective treatment, the reinforcement (or punishment) concepts were considered as a set so the student needed to reach criterion on both reinforcement (or punishment) concepts in order to be branched. If the student did not achieve total mastery on the pretest, then the criterion level adjusted to suggest a prior distribution slightly greater than .5 to the region above the criterion level: $(\pi-\pi_o/\underline{x},\underline{n}) \geq .5$, (where π_o equals the objective's criterion level, π equals the students true criterion level; $\underline{n}$ equals test length, and $\underline{x}$ equals student's score).

A member of the Beta class of distributions was selected to characterize prior learning in this binomial model. If the prior distribution is (a,b) and $\underline{x}$ success in $\underline{n}$ trials are observed, then the posterior distribution is $(\underline{x}+a, \underline{n}-\underline{x}+b)$. The posterior distributions and posterior probabilities of exceeding various criteria are provided in tables by Novick and Lewis (1974).

Prior to the premeasure, a loss ratio was set at 1.5 so that the disutilities associated with the error of a false retain were decreased relative to the error of a false advancement. A high score on the premeasure adjusted the ratio from 1.5 to 2.0. A student whose operating level was below that generated from the posterior distribution, retained the same parameters for the criterion level and loss ratio as before. A new instructional length was then generated. This procedure was reviewed after each response until the student either reached the criterion level or the pool of instances was exhausted.

Tests and Confidence Rating

The loss ratio for the Bayesian adaptive model was set from a 30 item, timed syllogism test (French, Ekstrom & Leighton, 1963). This test was selected

because of the need to measure an aptitude associated with the learning program (M. Koran & J. Koran, 1975). Since the structure of the instances required reasoning ability between the relationship of a stimulus (both attractive and aversive) and an outcome, the syllogism test would measure this aptitude.

For the prior Beta distribution used in the Bayesian adaptive strategy a pretest was given consisting of 20 items. Student test scores and on-task responses were weighted according to their confidence rating of each answer. A three choice confidence rating response format consisted of the following:

A. I am very sure of my answer.

B. I am fairly sure of my answer.

C. My answer is a guess.

Responses were weighted by increasing by a third a correct answer with a very sure confidence rating and a wrong answer with a guess confidence rating. That is, if a student answered an item correctly with a very sure confidence rating he or she would receive a score of 1.3. Responses were further weighted by decreasing by a third correct answers identified as a guess confidence rating (score was .6) or when a student was wrong but the confidence rating was very sure (score -.3). The maximum weighted pretest score was 7.8 per concept; using the mastery criterion level and number of incorrect items ($\underline{y}0$ from the pretest, the Beta distribution form was (7.8-y,y). On-task responses adjusted this distribution as follows: for a correct response the distribution form was (7.8-$\underline{y}$,$\underline{y}$ $\underline{z}0$) (where $\underline{z}$ is the confidence weighted correct response); for an incorrect response the distribution form was (8-$\underline{y}$ $\underline{z}$,$\underline{y}$).

Facilities

The study was conducted in the computer laboratory at Apple Valley Senior High School on January 10-13, 1977. Ten Texas Instrument teletype computer terminals (700 series) were used for the study. Each terminal operated at

30 characters per second. The terminals were on-line to the University of Minnesota's Control Data Corporation 6400 computer. Two assistants helped the experimenter sign students on the computer.

Procedures

The learning programs for the three treatments, except for the introduction, were presented via computer terminal. General directions were read by the experimenter, who then turned on the terminals and entered each student's identification number. After directions on operation of the terminal, students in all six groups were given a premeasure test on syllogisms. Upon completion of the premeasure, students were directed to start the pretest. Following the pretest, students were given a copy of the four concept definitions and began the learning program. The program was nonspeeded so the student could study both the definitions and presented instances as long as needed. When a student indicated completion of the program and was ready for the posttest the experimenter collected the copy of the definitions and entered the appropriate command on the terminal to start the posttest. Students left upon completion of the posttest.

Results

The data analysis consisted of a multivariate analysis of variance with univariate tests on each dependent variable followed by mean comparison tests (Student-Newman-Keuls and least significant difference). The independent variables were three forms of content structure (simultaneous, collective, and successive), while the multivariate dependent variables were correct score on the posttest and time on-task. An analysis of variance was used in testing both the effectiveness ratio (pretest score subtracted from the posttest score divided by time on-task) and the posttest confidence rating. The t-test was used to test pretest-to-posttest confidence rating changes. Means and standard deviations for the dependent variables of posttest correct score and time on-task are presented in Table 1.

Insert Table 1 about here

For the multivariate analysis of variance test we used as dependent variable posttest correct score and time on-task. Time on-task refers to the measured time period in which students were interacting with the learning program; this time did not include pretask time or posttest time. The posttest consisted of 24 items, six examples of each concept. The multivariate test on content structure was significant, $U(1,1,88)=.71$, $p<.001$. Two contrast tests were calculated. The first compared the simultaneous group against the collective and successive groups; and the test showed the hypothesized difference, $U(1,1,88)=.57$, $p<.001$. However, contrasting the collective group with the successive group resulted in no difference, $U(1,1,58)=83$, $p>.05$. Following are the results of the univariate tests on each of these two dependent variables, as well as the effectiveness ratio and confidence rating tests.

The analysis of variance test on the posttest correct scores showed a difference on the content structure variable $F(2,84)=6.13$, $p<.005$. A contrast test between the three groups, simultaneous versus collective and successive, resulted in a significant difference, $F(1,87)=5.07$, $p<.01$; the contrast between the collective and successive groups was nonsignificant ($p>.05$).

The univariate test on the content structure for time on-task was nonsignificant ($p>.05$). Average pretask time, including the syllogism test, pretest, and directions, for all groups was 12.9 minutes (no difference between groups, $p>.05$). On the posttest, the average time spent was 7.8 minutes (again, no statistical differences between groups, $p>.05$).

The fourth dependent variable represents an effectiveness measure of the learning treatments. Effectiveness is defined as student ability to perform skillfully and economically (Tennyson & Rothern, in press). The effectiveness ratio was calculated for each student by subtracting the pretest score from the posttest and dividing by time on-task. An analysis of variance test on content structure was significant, $F(2,84)=3.78$, $p<.05$. The contrast test of means showed that the simultaneous group was more effective than either the collective or successive $F(1,87)=3.24$, $p<.05$). The comparison between the collective and successive was nonsignificant ($p>.05$).

Univariate tests on the confidence rating scores for both the pretest and posttest were nonsignificant ($p>.05$). The analysis of variance test on pretest to posttest confidence gain scores was nonsignificant, $p>.05$. A t-test on confidence rating differences between the pretest and posttest per group showed a significant difference ($p<.01$); and average reported confidence increase of 14%. Thus, students reported lower confidence on the

pretest than posttest, but after participating in the learning program, students in all three treatments reported a higher level of confidence; even though learning performance and effectiveness differed significantly for the groups.

Discussion

Investigated in this research was the effect of content structure in terms of the sequential presentation order of coordinate concepts. Since previous research on concept acquisition has shown that discrimination between concepts is learned by presenting with examples, non-examples which share variable attributes, it was hypothesized that learning coordinate concepts could be facilitated by presenting such concepts simultaneously. By learning coordinate concepts at the same time student acquisition is enhanced because attention is focused on the contrasting differences between the various concepts.

Three sequences of the content elements were studied. These three sequences did not represent all possible combinations of the four coordinate concepts used in the study's learning program, rather the three sequences were based upon logically formed relationships between concepts in a hierarchical content structure. Elements of this structure include the variable attributes (associated with the subordinate concepts) and critical attributes. Also, the three sequences could be directly implemented into classroom related learning environments. In other words, the sequences were not studied as only laboratory manipulators. On the contrary, the sequences represent current curriculum design needs in regards to analysis of content for learning purposes. And, of course, the importance of testing methods for sequencing of concepts was shown in the significant results of this study.

Each of the three sequences investigated used previously defined methods for teaching generalization within a given concept class. The instances within each concept had divergent variable attributes and a range of difficulty. The difference between the three sequences was the method used to match the examples of one concept with examples of the other concepts. Although recent

concept research has shown that discrimination behavior is learned when non-examples are matched to examples on similarity of variable variables, the effect of that relationship had only been studied when learning one concept of a coordinate set. And, for coordinate concepts the objective is to learn to discriminate between all of the coordinate concepts. The three sequences thus held constant the variable of within concept instance relationships, while manipulating the between concept relationships. The simultaneous sequence was structured such that an example from each coordinate concept was represented in a rational set of instances. Within each rational set the instances had similar variable attributes, the difference being the critical attributes. That the simultaneous sequence succeeded in teaching discrimination is evident in the posttest results; the students performed (82%) above the .7 criterion level. While the students in the otehr two sequences had performances at the 66% level just below the .7 criterion level. In the collective sequence the coordinate concepts were clustered on the similarity of critical attributes. And, although the students were presented with the total range of the coordinate concepts, the clustering method of presenting one cluster group before another group prevented focusing on the differences between the non-clustered critical attributes. In the learning program used in this study, the two critical attributes positive action (reinforcement) and negative action (punishment) were clustered into two separate groups, thus students did not see the contrast of those two attributes in a presentation form. Students in the successive condition had a similar learning situation, but they were presented the concepts without any matching.

Time on-task between the three sequences was nonsignificant. However, on the effectiveness ratio, the simultaneous condition was better in terms of

learning performance and time required for that learning. Student responses on the posttest showed that in all treatment groups students classified correctly the examples from the positive reinforcement and negative punishment concepts, but the students in the simultaneous condition, who were presented the contrast between all the coordinate concepts, classified correctly the negative reinforcement and positive punishment concepts. In the adaptive control system, the students in the simultaneous group received a prescribed number of instances per concept, thus as a concept was learned the instances from that concept were eliminated from the rational sets. And, since the two most easily learned concepts were positive reinforcement and negative punishment, those were dropped from the instruction and the remaining two, negative reinforcement and positive punishment, were highlighted. This sequential possibility was not possible for the other two sequences. It could be pointed out that with a collective treatment of negative reinforcement and positive punishment would be an equivalent sequence, however, that arrangement would be only task specific, not a generic variable. Any predetermined clustering might prevent successful learning because of individual differences inherent in any given student group.

In summary, this study has demonstrated that the sequencing of content elements is an important variable in curriculum design. The implications of this study, when combined with the previously reviewed concept research, are that content should be presented in a contextual form and that the selected instructional stimuli should be arranged to accentuate both the differences between the coordinate concepts and the scope of each concept. A two-step process is proposed from the findings. First, the content structure is determined; the three levels of concepts--superordinate, coordinate, and subordinate--are analyzed with identification of critical and variable attributes.

Second, the instances are arranged in rational sets by appropriate manipulation of the attributes; within a rational set, containing one example from each coordinate concepts, the instances should have similar variable attributes. This two-step design strategy provides an objective means for selecting and arranging instructional materials. Certainly, this method would increase the effectiveness of instructional materials, and perhaps decrease the development costs by reducing revisions in the formative evaluation process.

References

Bruner, J. S. The process of education. Cambridge, Massachusetts: Harvard University Press, 1960.

Dewey, J. Democracy and education. New York: Macmillan, 1916.

Gagné, R. M. The conditions of learning (2nd Ed.). New York: Holt, Rinehart & Winston, 1970.

Houtz, J. C., Moore, J. W., & Davis, J. K. Effects of different types of positive and negative instances in learning "nondimensioned" concepts. Journal of Educational Psychology, 1973, 64, 206-211.

Jenkins, J. J. Remember that old theory of memory? Well, forget it! American Psychologist, 1974, 29, 785-795.

Klausmeier, H. J. Instructional design and the teaching of concepts. In J. R. Levin & V. L. Allen (Eds.), Cognitive learning in children. New York: Academic Press, 1976.

Klausmeier, H. J., Ghatala, E. S., & Frayer, D. A. Conceptual learning and development, a cognitive view. New York: Academic Press, 1974.

Koran, M., & Koran, J. Jr. Interaction of learning aptitudes with question pacing in learning from prose. Journal of Educational Psychology, 1975, 67, 76-82.

Merrill, M. D., & Tennyson, R. D. Concept teaching: An instructional design guide. Englewood Cliffs, New Jersey: Educational Technology, 1977a.

Merrill, M. D., & Tennyson, R. D. Concept classification and classification errors as a function of relationships between examples and nonexamples. Improving Human Performance, 1977b.

Posner, G. J. The extensiveness of curriculum structure: A conceptual scheme. Review of Educational Research, 1974, 44, 401-407.

Rugg, H. The foundations of curriculum making. The twenty-sixth yearbook: Part II. The National Society for the Study of Education: Public School Publishing Company, 1927.

Stolurow, K. A. C. Objective rules of sequencing applied to instructional materials. Journal of Educational Psychology, 1975, 67, 909-912.

Suppes, P. Mathematical concept formation in children. American Psychologist, 1966, 21, 139-150.

Tennyson, R. D. Effect of negative instances in concept acquisition using a verbal learning task. Journal of Educational Psychology, 1973, 64, 247-260.

Tennyson, R. D., & Boutwell, R. C. A quality control design for validating hierarchical sequencing of programmed instruction. NSPI Journal, 1971, 10, 5-10.

Tennyson, R. D., & Rothen, W. Pretask and on-task adaptive design for selecting number of instances in concept acquisition. Journal of Educational Psychology, in press.

Tennyson, R. D., Steve, M., & Boutwell, R. C. Instance sequence and analysis of instance attribute representation in concept acquisition. Journal of Educational Psychology, 1975, 67, 821-827.

Tennyson, R. D., & Tennyson, C. L. Simultaneous presentation of rules and interdisplay relationship of instances in a verbal task. Journal of Educational Psychology, 1975, 67, 852-859.

Tennyson, R. D., Woolley, F. R., & Merrill, M. D. Exemplar and non-exemplar variables which produce correct concept classification behavior and specified classification errors. Journal of Educational Psychology, 1972, 63, 144-152.

Tyler, R. W. Basic principles of curriculum and instruction. Chicago: University of Chicago Press, 1950.

Woolley, F. R., & Tennyson, R. D. Conceptual model of classification behavior. Educational Technology, 1972, 12, (4), 37-39.

Table 1

Means and Standard Deviations for Posttest Correct Scores and Time On-Task

Content Structure	Dependent Variables	
	Posttest Correct Score	Time On-task
Simultaneous		
M	19.7	10.3
SD	2.9	2.9
Collective		
M	16.3	13.9
SD	3.0	4.3
Successive		
M	15.3	14.3
SD	3.7	5.8

Note. Maximum posttest score = 24.